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Subject: Forest Hill Functional Assistance Trip, Oct 6,
Bear Trap Compartment, Cavanah Ridge, Peavine Ridge (Report #NE96-2)

To: District Ranger, Foresthill RD, Tahoe NF

On October 6, FPM Plant Pathologist Bill Woodruff joined Gail Parn, District Silviculturist to examine the Greek Store, Cavanah Ridge, and Peavine areas of the Forest Hill RD to assess the disease situation in each. The objective of this visit was to provide information on forest diseases for use in preparing silvicultural prescriptions for future stand management.

BEAR TRAP COMPARTMENT

OBSERVATIONS

This area was evaluated for annosus root disease. The stand visited is in the Bear Trap Compartment north of Greek Store. The stand is a 100 to 150 year old mixed conifer stand which is dominated by white fir. Also present are ponderosa pine, sugar pine, and incense cedar. Old growth pine stumps in the area indicate 200-400 year old pine were dispersed throughout the stand, prior to recent logging. The overstory is composed mostly of white fir with 10" to 24" dbh. Stocking is estimated to be 140 to 240 trees per acre with 160 to 260 square feet of basal area. Scattered clumps of conifers may go up to 300 square feet. Shrubs present are whitethorn, greenleaf manzanita, chinkapin and ribes. The management objective for the compartment is to manage the forest for wood and fiber production, within the constraints imposed for protection of the California spotted owl.

The few acres of the stand that were examined appeared representative of much of the area of interest. Spore producing basidiocarps (conks) of Heterobasidion annosum were identified in most of the large fir stumps that were examined. Some small windthrown white fir showed signs of annosus root disease in the laminated decay that was present. A few white fir appear to be dying annually. This may be due to overstocking in combination with infected root systems and bark beetle attacks. Many of the standing and fallen fir mortality exhibited fir engraver galleries (Scolytus ventralis). No H. annosum was found in pine or incense cedar stumps. An occasional sugar pine was infected with white pine blister rust, caused by Chronartium ribicola.

DISCUSSION

The amount of annosus root disease in the Bear Trap Compartment is most probably higher than natural, due to previous logging disturbance. Untreated stumps and wounds near the ground on residual white fir, are ideal infection courts for airborne H. annosum spores that are present in western coniferous forests. Both these conditions existed during past logging. Today, we recognize the importance of treating stumps and protecting residual conifers to maintain endemic levels of H. annosum.

Annosus root disease in living fir trees is hard to detect, since the fungus does not usually kill fir. It generally weakens roots and reduces the growth potential of root systems. H. annosum, in true fir, grows in small roots, in woody portions of larger roots, and in the heartwood at the base of the tree (butt rot). It seldom grows into the bole of the tree. H. annosum enters fir root systems through fire scars, wounds, and freshly cut stump surfaces. Once in the roots, the fungus persists as long as there is sound wood on which to grow. The fungus is capable of infecting, via root contact, the roots of adjacent true fir, Douglas-fir, and giant sequoia.

Living true fir often grows new wood faster than H. annosum decays it. For this reason, the disease is not generally fatal to its host. The primary impact of fir annosus (also known as "s-type" annosus) on the fir in a mixed conifer stand is to reduce growth and increase wind-throw. Fir mortality can result from s-type H. annosum when the host is further stressed by drought, competition, or insect attack; or when the tree blows over. In contrast, pine annosus (or "p-type") can kill its host by itself since, unlike the s-type, it colonizes the sapwood and inner bark, and kills the cambial tissues at the root collar. For more information on this disease, please refer to FSH 3409.11, R5 Supplement No. 3409.11-94-1, attached to this report.

ALTERNATIVES

There are several ways to manage stands infested with s-type H. annosum. Below are listed five alternatives. When harvesting conifers, it is important to recognize that the freshly created stumps are ideal infection courts for airborne H. annosum spores. Treating fresh stumps with a registered borate compound, will reduce the likelihood of introducing annosus root disease into healthy root systems. Sporax is currently, the borate compound that is available and registered in California for treating conifer stumps (Sporax label information is included with this report). In the Bear Trap Compartment, all freshly cut pine stumps should be treated with Sporax in an effort to prevent introducing p-type annosum to the stand. Since it is impossible to know from outward appearance that any white fir is free of H. annosum, the decision to treat white fir stumps with Sporax should be made with the management objectives in mind. Where white fir will be retained, Sporax may be used to prevent an increase of the s-type annosum. Where pine will be planted, and the existing fir roots will decay before white fir is reintroduced, stump treatment may not be necessary. Borate treatment of all conifer stumps, however, could be used to mitigate the effect of exposing hosts through timber harvest.

1. No action. The trees and other vegetation will continue growing, reproducing, and dying. Annosus root disease will continue to feed on the sound wood in the roots. Slow growing fir,

infected with H. annosum, are not able to produce wood fast enough to offset the losses sustained from wood decay. As stocking increases, trees will be stressed and some will continue to die due to H. annosum, other diseases and/or insects. Eventually, the amount of dead, woody fuel present will reach a point where fire will easily carry through the stand. When conditions are favorable, the stand will burn. At first, brush will probably replace most of the trees. In time, a mixed conifer forest will displace the brush. The long time required for natural regeneration (over fifty years) should be sufficient time for fir roots to be completely decayed by H. annosum and other decomposers. At this point most of the H. annosum will have died. The root disease in the stand could thus revert to endemic levels.

2. Clearcut, plant with pine. This would convert the stand to pine which is resistant to fir annosus. In the long run (hundred years or more), white fir would seed in from the edge of the clearcuts. If more white fir is desired, fir could be planted in openings created by previous logging, where infected fir roots are mostly decomposed. This alternative would be similar to a natural system, where a fire of moderate intensity would kill most of the white fir, and leave a number of pine seed trees. In time, the level of s-type H. annosum in the fir roots would be reduced to endemic levels.
3. Patch cut, plant with pine. By removing all the trees from portions of the stand, and planting pine (non-host trees), the amount of H. annosum would be significantly reduced in the cleared areas, as the white fir roots decayed. Eventually, white fir would seed in from surrounding trees after most of the H. annosum in the decaying roots had died. Over time, additional patch cuts could be created which would blanket the whole stand, thus significantly reducing the level of annosus root disease to something close to the endemic level in the centers of the patches. The edge areas of the patches would retain higher levels of root disease since these areas would be harvested last, and some natural fir regeneration could become established in the root zone of infected fir prior to harvest. The amount of annosus root disease in the stand would be greater than in Alternatives 1 or 2. In the short run, the species composition would be shifted heavier to pine, which is resistant to the s-type H. annosum.
4. Shelterwood with white fir, plant with pine. By leaving a shelterwood of the healthiest white fir, and planting pine, the amount of annosus root disease in the stand could be reduced. The amount of reduction in root disease would be in proportion to the number of infected fir harvested, less the number of naturally regenerating fir that become infected from residual fir trees. The residual amount of H. annosum root disease would be greater than Alternatives 1, 2 and 3, since infected shelterwood fir would remain. However, as in Alternatives 2 and 3, the species composition of the stand would be heavier to pine, thus reducing the impact of fir annosus on the stand. If the residual fir trees could be harvested, or killed, while fir regeneration was small, the likelihood of infecting the new fir trees would be reduced.
5. Thin and sanitize the stand, plant openings with pine. By removing the least vigorous fir, and then thinning the remaining stand, the growth loss caused by the annosus root disease can be minimized. By removing some of the competing trees, the residual fir trees could be released to grow and produce future crop trees. This is because fast growing fir can grow new wood faster than the H. annosum decays the old wood. The planted pine will be resistant to the s-type annosus. The level of annosus root disease in the stand will not be significantly reduced. However, the effects of the disease could be reduced. In future entries, more pine can be planted in future openings. As pine (and incense cedar) become more prevalent in the stand, the amount of annosus root disease will be lower since white fir is the only stand component affected by the H. annosum (s-type) that is present.

SUMMARY

H. annosum in the Bear Trap Compartment, in combination with overstocking, other diseases and insect attack, will contribute to future conifer mortality in the area. The level of annosus root disease in the stand is high due to past disturbance. Unmanaged, the disease level will eventually return to natural

levels if fire burns the stand and natural reforestation occurs over 50 years or more. However, the annosus root disease can be managed to a lower level by harvesting white fir, and replanting pine which is resistant to the s-type annosus present in the white fir. Alternatively, white fir infested with H.annosum can be managed and grown to maturity by thinning the fir so that the residual trees can outgrow the effects of the disease.

CAVANAH RIDGE

OBSERVATIONS

This area was evaluated for dwarf mistletoe. The stand visited is in the Cavanah Compartment on Cavanah Ridge. The stand is composed of an overstory of large (200 to 400 year old) sugar pine, ponderosa pine, Douglas-fir and incense cedar. Overstory density was estimated to be 5 to 12 trees/acre, and was generally distributed in clumps. Sugar pine dwarf mistletoe (Arceuthobium californicum), western dwarf mistletoe in ponderosa pine (A.campylopodum), and Douglas-fir dwarf mistletoe (A.douglasii) were detected. The understory is composed of mixed conifers (sugar pine, ponderosa pine, Douglas-fir, incense cedar, and white fir) mostly smaller than 8" dbh. In the understory, dwarf mistletoe was detected in the sugar pine and ponderosa pine. Using the Hawksworth six point disease rating system, the dwarf mistletoe in the overstory is of medium intensity (Hawksworth 2 to 4) and that in the understory is light (Hawksworth 1 to 2). Understory tree density was estimated to be 300 trees/acre, and was also somewhat clumped in distribution. Shrubs present are shrub tanoak and greenleaf manzanita. The management objective for the compartment is to manage the forest for wood and fiber production, within the constraints imposed for protection of the California spotted owl.

DISCUSSION

The dwarf mistletoe is slowly intensifying in both the overstory and understory. The dwarf mistletoe plants on the overstory trees will continue dispersing seed onto the understory, infecting healthy trees and further intensifying the disease on those already infected. Biological information on dwarf mistletoe is attached to this report.

A key fact about dwarf mistletoe is that each dwarf mistletoe species infects only one or two tree species. A.campylopodum infects ponderosa and Jeffrey pine, A.californicum infects sugar pine, A.abietinum infects true fir, and A.douglasii infects Douglas-fir and sometimes true fir. Also, discharged dwarf mistletoe seed may travel horizontally for 20 to 60 feet from plants in overstory trees. With the aid of wind, dwarf mistletoe seed may travel up to 100 feet. With this dwarf mistletoe biology in mind, it is possible to manage the infested mixed conifer stands in the Cavanah Compartment to reduce the spread and impact of this disease. Several alternatives are discussed below.

ALTERNATIVES

1.No action. The trees and other vegetation will continue growing until the site becomes overstocked. In the understory, dwarf mistletoes will continue to intensify as the existing infestation spreads and as new infections result from overstory seed dispersal. The dwarf mistletoe could increase in the understory at the rate of one Hawksworth rating, or more, each decade. Thus, in about 30 or 40 years, the disease could be seriously stressing both the understory and overstory. In the meantime, trees will be increasingly stressed by overcrowding and insect attack. The result will be increasing

tree mortality, accompanied by fire. Frequent, natural fires, can reduce the amount of dwarf mistletoe in a forest by burning heavily infected trees, or groups of trees, and by killing heavily infected branches near the ground. On the other hand, by artificially keeping fire out of the forest, dead/dying trees and other fuels tend to accumulate in unmanaged forests to a point where wildfire will eventually kill most of the living trees in a stand.

2. Remove the diseased overstory trees; thin and sanitize the understory. When managing forests infested with significant amounts of dwarf mistletoe, it is important to consider the infected overstory trees. The higher the dwarf mistletoe plant is in the canopy, the further the seed can be discharged. In addition, dwarf mistletoe seed coming from above has a good chance of infecting the tops of understory trees, where the most serious damage can occur. The rate of spread of dwarf mistletoe to the understory can be most effectively decreased by removing the overhead dwarf mistletoe seed source. One way this can be done, is by harvesting the diseased trees. Alternatively, dwarf mistletoe plants can sometimes be successfully removed from overstory trees through pruning. However, pruning is costly, not always effective, and generally recommended only in recreation areas.

Once the overhead source of dwarf mistletoe seed is controlled, it is reasonable to remove and/or prune infested understory trees. In addition to sanitizing the stand, it is important to reduce the stocking of both overstory and understory trees to promote vigorous growth. Vigorous trees are more resistant to the effects of disease, drought, and insect attack.

NOTE: When pruning dwarf mistletoe infected branches to control this disease, it is important to recognize certain limitations (in addition to the cost). Once infecting the host, dwarf mistletoe takes several years to grow visible shoots, by which this disease can be recognized. Also, the roots of dwarf mistletoe in conifer branches extend a distance beyond the visible aerial shoots of this disease, often into the bole of the host tree. Therefore, pruning treatments leave behind an unknown amount of latent infection. This latent infection will show up several years later and needs to be dealt with at the time. If a high level of dwarf mistletoe control is desirable, future treatments should be scheduled. It is wise to plan at least two follow-up treatments, at five year intervals, after the initial pruning, to remove newly emerging latent infections.

3. Manage non-host trees Since dwarf mistletoe has a limited spread radius, and since the dwarf mistletoes are host specific, it is possible to retain infected trees in the overstory and manage non-host regeneration in the understory. For example, where A. campylopodum infests the ponderosa pine in the overstory, sugar pine, white fir, Douglas-fir and incense cedar could be managed in the understory. In the Cavanah Compartment, there is much diversity in both the understory and the overstory which will enable this option to be implemented.

In the Cavanah Compartment, there is much advanced regeneration, free of visible dwarf mistletoe. These trees may be the most desirable component of the stand. In this case, "same-host" overstory trees infected with dwarf mistletoe, within about 100 feet of the desirable understory regeneration should be removed. This can reduce the number and severity of new dwarf mistletoe infections. However, as discussed in Alternative 2, latent

infections should be treated five to ten years after the initial treatment. Also, a stocking level in the overstory and understory should be created which will enhance tree growth and thus provide resilience to disease, drought and insect attack.

SUMMARY

In the Cavanah Compartment, dwarf mistletoe is impacting the sugar pine and ponderosa pine. Fire is a natural process which has regulated dwarf mistletoe in the past. Due to fire exclusion practices over the last hundred years, the disease is intensifying. To control the dwarf mistletoe two alternatives are proposed. One treatment involves removing the diseased overstory trees and thinning and sanitizing the understory. The other involves favoring non-host conifers, when managing in the presence of a particular species of dwarf mistletoe. The two alternatives are not mutually exclusive. In either alternative, it is important to plan for latent infections after the initial treatment, and to adjust stocking levels to produce vigorously growing trees which are more resilient to disease, drought and insect attacks.

PEAVINE RIDGE

OBSERVATIONS

In the Peavine area, several plantations were examined to determine if white pine blister rust (*Cronartium ribicola*) is seriously affecting the planted sugar pine. The plantations are evenaged and well stocked with ponderosa pine, sugar pine, Douglas-fir, white fir, and incense cedar. Trees are mostly sapling size. One plantation had some pole sized trees. Stocking was estimated to range from 250 to 500 trees per acre. Tree health appeared good. One to three white pine blister rust infections were present on several of the sugar pine. Brush species present are green-leaf and white-leaf manzanita, bush tanoak, and bear clover. Beargrass was also common.

DISCUSSION

Very little white pine blister rust was present on the sugar pine. Therefore, no treatment for this disease is recommended. However, the plantations appeared to be overstocked. One of the older plantations was being thinned during this visit. In future thinnings, the few sugar pine with blister rust might be removed or pruned. This would provide growing room for adjacent trees or remove cankers that could eventually impact the bole of the host. However, a special project to treat the blister rust is not needed as the infections are few and the sugar pine stocking is sufficient to produce a large number of mature sugar pine in the future.

I hope the above information is useful for your purposes. Please contact me at (916) 257-2151 with questions or requests for future assistance.

BILL WOODRUFF
Enclosures

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK
R5 SUPPLEMENT 3409.11-94-1
EFFECTIVE 5/17/94

CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology.

- a. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113° F (45°C) and mycelium in wood is killed after exposure for one hour at 104° F (40°C). Temperatures just

below the stump surface commonly reach or exceed the thermal inactivation level (400 C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40°C in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impending failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H. annosum. Use the following similar symptoms for correct diagnosis:

- a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.
- b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.
- c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the

wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no

economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

- a. The objectives and management direction for the stand.
- b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.
- c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand may be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable

hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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Dwarf Mistletoes, Impact and Biology

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts. Western dwarf mistletoe (A. campylopodum) infects principally ponderosa and Jeffrey pines, and occasionally lodgepole pine. White fir dwarf mistletoe (A. abietinum f.sp. concoloris) infects white and sugar pine (rare). Red fir dwarf mistletoe (A. abietinum f.sp. magnificae) infects only red fir.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and the seeds are forcibly discharged from the aerial shoots. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues, developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occasionally vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. In grey pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year, due to the thin crown of this pine. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached, and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches-broom (tightly grown clump of vegetation on a branch) in the lower crown, and bole swellings.

Dwarf mistletoes were found on ponderosa pine, sugar pine and Douglas-fir in the Cavanah Compartment. The disease is present on pine of all sizes and ages, and on several Douglas-fir saplings. Where seedlings have established under infected overstory pine, the seedlings are often infected. Medium infestations kill branches, cause the development of witches-brooms, and severely weaken the pine. Weakened trees are usually killed when other agents (such as bark beetles, root diseases, or drought) occur. However, dwarf mistletoe is capable of killing pine seedlings and saplings, by itself, when the infections are heavy. Light infestations have little effect on individual pine trees. However, light infestations will develop into heavy infestations in 40 or 50 years. When using the Hawksworth six class dwarf mistletoe rating system, it is estimated that the disease will increase one point in severity, per decade. In addition, the disease spreads from tree to tree at various rates, depending on stand density and the position of the dwarf mistletoe plants in the crown.

Dwarf mistletoe can occur on white and red fir. The impact of the dwarf mistletoe on the fir is less pronounced and generally not significant. Where dwarf mistletoe infests white fir heavily, the fungus Cytospora abietis will often infect the white fir also and cause cytospora canker. The cytospora is considered secondary, since the trees are usually heavily impacted by dwarf mistletoe when the cytospora infects.